This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

As rescanning documents *will not* correct images, please do not report the images to the Image Problem Mailbox.

RESERVE COPY.

PATENT SPECIFICATION

DRAWINGS ATTACHED

885,093

Date of filing Complete Specification April 26, 1960

Application Date May 1, 1959. *No. 15038/59.*

Complete Specification Published Dec. 20, 1961.

Index at acceptance:—Class 110(3), J1X.

International Classification:—F02k.

COMPLETE SPECIFICATION

Improvements in or relating to Jet Propulsion Nozzles

I, ALEC DAVID YOUNG, a British Subject, of "The Sycamores", Whitehall Lane, Buckhurst Hill, Essex, do hereby declare the invention, for which I pray that a patent may be granted to me and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to apparatus for partially inhibiting the generation of noise by a high velocity jet issuing from a nozzle into ambient atmosphere.

The noise generated by a high velocity jet is created to a large extent by the intense vortices of annular shape existing in an annular zone near to and beyond the nozzle exit where there is a steep velocity gradient across the boundary of the jet and the ambient fluid. This zone is known as the mixing region of the jet. If the regularity of the pattern of these vortices can be broken up and their intensity reduced, the overall noise level can be correspondingly reduced. It can be inferred that by controlling the jet flow in such a way as to produce irregular formations of large but weak vortices, rather than regular small vortices of strong intensity, a useful reduction of noise level will result and this reduction should be most marked in the higher frequency ranges which are found to be particularly unpleasant to the human ear. It is also desirable that the mixing region should be reduced in length by increasing the rate of mixing immediately downstream of the nozzle exit.

The term "non-stalled" as used herein means making an angle of incidence not greater than the angle of maximum lift coefficient.

The present invention provides apparatus for partially inhibiting the generation of noise by a high velocity fluid jet issuing from a jet pipe nozzle exit into ambient atmosphere, the jet pipe nozzle having mounted substantially radially thereon in the region only of the exit a plurality of vanes, which in an operative position are inclined over a major portion of their length, and in non-stalled relationship to the general fluid flow direction through the nozzle.

The vanes may be mounted on the inner periphery of the jet pipe nozzle. In addition, or alternatively, vanes may be mounted on the outer periphery of the jet pipe nozzle. When vanes are mounted both on the inner and outer periphery of the jet pipe nozzle, the inner and outer vanes in an operative position may be inclined with respect to one another. The outer vanes may be provided with shrouds and the shroud provided with apertures.

The apparatus may incorporate means for adjusting the inclination of the vanes with respect to the general flow direction through the nozzle and the vanes may be of twisted form.

In an alternative arrangement according to the invention, the vanes may be attached to the jet pipe nozzle by means which permit oscillation between inclination angles of a different sense. The inner vanes may oscillate out of phase with the outer vanes. The vanes may extend downstream of the jet pipe nozzle and means may be provided for the locking of the vanes in alignment with the general flow direction through the nozzle.

The invention will now be described with reference to the accompanying diagrammatic drawings, in which:—

Figure 1 shows an end view of a jet nozzle provided with vanes on the inner periphery of the nozzle;

Figure 2 shows a nozzle provided with vanes on the outer periphery of the nozzle as well as with vanes on the inner periphery of the nozzle;

Figure 3 shows a modified form of the nozzle shown in Figure 2;

Figure 4 shows a developed view of the nozzle shown in Figure 3;

Figure 5 shows a perspective view of the nozzle shown in Figure 3;

Figure 6 shows a nozzle similar to that shown in Figures 3 and 5 but including means for adjusting the position of the vanes;

Figure 7 shows a nozzle similar to that shown in Figures 3 and 5 but with the outer vanes shrouded;

Figure 8 shows a nozzle similar to that shown in Figure 7;

Figure 9 shows a nozzle with vanes which are mounted for oscillation;

Figures 10 and 11 show a nozzle similar to that shown in Figure 9 with an alternative vane mounting arrangement;

In each of the embodiments hereinafter described the vanes, when in a noise suppressing position, (hereinafter referred to as an "operative position") are in non-stalled relationship to the general fluid flow direction through the nozzle. In the cases where the vanes are mounted for oscillation, the maximum angle the vanes make with the general fluid flow direction is still such that the vanes are in non-stalled relationship to the fluid flow.

Figure 1 shows the rear end of a jet pipe nozzle 2, the inner periphery of which is provided with vanes 1, which project into the jet flow. These vanes are inclined along the whole of their length with respect to the general flow direction through the jet pipe nozzle.

The vanes 1 in Figure 1 of the drawings serve to deflect the jet flow away from the general direction of flow through the nozzle 2. The vanes produce flows inclined with respect to the flow in the central region of the jet. These deflected flows interact with the flow in the central region of the jet and as a consequence are induced to swirl. The swirling flows effect more rapid mixing between the jet and the ambient fluid surrounding the nozzle 2, as well as inhibiting the formation of regular annular vortices otherwise formed in the mixing region of the jet. Furthermore, the vanes also assist in reducing the axial extent of the mixing region downstream of the exit of the nozzle 2.

Figure 2 shows a nozzle 2 provided with inner vanes 1, the nozzle also having around its outer periphery vanes 4. The inner and outer vanes 1 and 4 are substantially opposite one another and inclined along the whole of their length with respect to the general flow direction through the nozzle in a different sense.

In Figure 2, the outer vanes 4 deflect the flow of surrounding ambient fluid from what would have otherwise been its direction of flow in an anti-clockwise direction (as viewed from the downstream end of the nozzle). The jet flow flowing over the inner vanes 1 is deflected in a clockwise direction. The flows deflected by the inner and outer vanes 1 and 4 interact with one another and the flow deflected by the vanes 1 contacts the flow in the central region of the jet to impart swirl thereto. The contra-rotating swirls thus formed inhibit the formation of the regular annular vortices in the mixing region of the jet and also tend to increase the rate of mixing between the ambient and jet flows.

In Figure 3 the vanes 1 and 4 are displaced relatively to each other and this arrangement of vanes is shown more clearly in the developed view of the nozzle shown in Figure 4 and the perspective view in Fig. 5.

The nozzle arrangement shown in Figure 3 operates in a similar manner to that shown in Figure 2.

The developed view of the nozzle 2 shown in Figure 6 has vanes 1 and 4 which are each mounted on a pivot pin 7. The upstream end of each of the vanes 1 is pivotally joined to a linkage 9. The linkages 9 are in turn joined to a connecting ring 10 which is provided with an operating rod 11. Similarly the upstream end of each of the vanes 4 is pivotally joined to a linkage 12. The linkages 12 are in turn joined to a connecting ring 13, provided with an operating rod 14. Operating rods 11 and 14 respectively are each provided with a locking mechanism 11A and 14A.

The nozzle apparatus shown in Figure 6 of the drawings incorporates means for adjusting the inclination of the vanes with respect to the general flow direction through the nozzle. Movement of the operating rod 11 in the direction shown by arrow A displaces the connecting ring 10 in the same direction and consequently pivots each of the vanes 1 from the position shown in broken line to a position in which the vanes 1 lie normal to the nozzle exit. Similarly the vanes 4 may pivot to a position 4A shown in dotted line by movement of the operating rod 14 in the direction of arrow B. Thus when the vanes 1 and 4 are brought to lie normal to the nozzle exit little or no noise suppression effect is obtained. In an aircraft application, during take-off of an aircraft the vanes will be inclined at an angle relative to a plane through the longitudinal axis of the nozzle. The vanes 1 and 4 can be locked in either the inclined position or the normal position by placing the operating rods 11 and 14 in the appropriate slot in the locking mechanisms 11A and 14A. Such an arrangement of adjustable vanes has the advantage that any thrust loss due to the inclination of the vanes only occurs when the vanes are in their operative position. When the aircraft has climbed to a height at which the noise is no longer a problem, the vanes can be pivoted into the position in which the vanes 1 lie normal to the nozzle exit, and the

8. Apparatus as claimed in Claim 7, in which the outer vanes are twisted in a different sense from that of the inner vanes.

9. Apparatus as claimed in any of Claims 1 to 3, in which the vanes are attached to the jet pipe nozzle by resilient means, which permit oscillation between inclination angles of a different sense.

10. Apparatus as claimed in Claim 9, in which the inner and outer vanes are arranged to oscillate out of phase.

11. Apparatus as claimed in any of Claims 1 to 10, in which the vanes extend downstream of the jet pipe nozzle exit.

12. Apparatus as claimed in Claim 9, in which means are provided for locking the vanes in alignment with the general direction of flow through the nozzle.

13. Apparatus substantially as described with reference to Figures 1 to 5 or 7 or 8 of the drawings accompanying the complete specification.

14. Apparatus substantially as described with reference to Figure 9 of the drawings accompanying the complete specification.

15. Apparatus substantially as described with reference to Figures 6, 10 and 11 of the drawings accompanying the complete specification.

C. E. BELL,
Chartered Patent Agent,
25, Green Street, London, W.1,
Agent for the Applicant.

PROVISIONAL SPECIFICATION

Improvements in or relating to Jet Propulsion Nozzles

I, ALEC DAVID YOUNG, a British Subject, of "The Sycamores", Whitehall Lane, Buckhurst Hill, Essex, do hereby declare this invention to be described in the following statement:—

This invention relates to apparatus for partially inhibiting the generation of noise created by a high velocity jet issuing from a nozzle into ambient fluid.

The noise generated by such a high velocity jet is created to a large extent by the intense vortices of annular shape existing in an annular zone near to and beyond the nozzle exit where there is a steep velocity gradient across the boundary of the jet and the ambient fluid. This zone is known as the mixing region of the jet. If the regularity of the pattern of these vortices can be broken up and their intensity reduced, the overall noise level can be correspondingly reduced. It can be inferred that by controlling the jet flow in such a way as to produce irregular formations of large but weak vortices, rather than regular small vortices of strong intensity, a useful reduction of noise level will result and this reduction should be most marked in the higher frequency ranges which are found to be particularly unpleasant to the human ear. It is also desirable that the mixing region should be reduced in length by increasing the rate of mixing immediately downstream of the nozzle exit.

The present invention provides apparatus for partially inhibiting the generation of noise created by a high velocity jet issuing from a nozzle into ambient fluid, said nozzle being provided with several vanes, the vanes at least in an operative position, being skewed with respect to a plane passing through the longitudinal axis of both the nozzle and the nozzle wall, in non-stalled relationship to the flow over the vanes, in such a manner that the vanes deflect a part of the flow into a direction with a component of motion, tangential to the remainder of the flow.

Vanes may be positioned on the outer periphery of the nozzle, these vanes extending away from the longitudinal axis of the nozzle and also on the inner periphery of the nozzle, these vanes extending towards the longitudinal axis of the nozzle. The inner and outer vanes may be positioned substantially opposite one another and may be differently skewed with respect to the plane passing through the longitudinal axis of both the nozzle and the nozzle wall. Alternatively, vanes may be positioned around the outer or inner periphery of the nozzle only. The vanes may lie in an axial plane of the nozzle. The outer vanes may be shrouded and the shroud provided with apertures.

The nozzle may incorporate means for adjusting the inclination of the vanes with respect to the plane through both the longitudinal axis of the nozzle and the nozzle wall and some or all of the vanes may be of twisted form.

In an alternative arrangement according to the invention, the vanes may be attached to the jet pipe by flexible or pivotable means, thus permitting the vanes to oscillate about substantially radial axes between inclination angles of a different sense. Outer and inner vanes may oscillate out of phase. The vanes may be positioned downstream of the nozzle exit and means may be provided for the locking of the vanes in alignment with the jet axis.

The invention will now be described with reference to the accompanying diagrammatic drawings, in which:—

Figure 1 shows an end view of a jet nozzle provided with skewed vanes projecting into the jet flow;

Figure 2 shows a nozzle provided with skewed vanes on the outer periphery of the

aircraft will not incur any additional thrust loss penalty.

In Figure 7, the outer vanes 4 are provided with a shroud 5 which is provided with a series of apertures 6, and in Figure 8 the inner and outer vanes 1 and 4 respectively are of twisted form. The twist on the inner vanes 1 is in the opposite direction to the twist on the outer vanes 4.

Ambient air surrounding the nozzle 2 is either entrained between the spaces defined between adjacent pairs of vanes 4 and the shroud 5 or the ambient air in these spaces is passed out through the apertures 6, depending on pressure conditions obtaining in the space. Such an arrangement will further assist mixing between the jet flow and the ambient fluid surrounding the nozzle 2. The arrangement shown in Figure 8 in which the outer and inner vanes are twisted in opposite directions further assist this mixing process.

Figure 9 shows a nozzle 2 with an outer fairing 2A. Spacing members 15 are provided between the nozzle 2 and the outer fairing 2A. In order to show the nozzle arrangement more clearly both the nozzle 2 and the fairing are shown in cross-section but in practice the fairing 2A would be smoothly joined to the nozzle 2 downstream of the plane shown in cross-section. Pivot pins 7 are firmly mounted between the nozzle 2 and the fairing 2A through the spacing members 15. Each of the pivot pins 7 projects inwardly towards the longitudinal axis of the nozzle. Vanes 1 are each provided at their upstream ends with a pair of lugs 8 which are mounted on pivot pins 7 so that the vanes 1 are free to pivot. A coil spring 8A surrounds each of the pivot pins 7 and is attached to the lugs 8 of the vanes 1 and to the pins 7.

In Figure 9 the vanes 1 are pivotally mounted and thus the vanes can oscillate between inclined angles on either side of the position of equilibrium of the vanes as shown in full lines. The frequency and amplitude of the oscillation is dependent on the resilience of the spring, the velocity of the jet and ambient flows, the turbulence in the jet flow and the vane inertia. The oscillation of the vanes 1 induces corresponding oscillation in the flow direction of the jet gases and consequently inhibits the formation of the regular annular vortices as well as reducing the extent of the mixing region.

Figure 10 shows an arrangement similar to that shown in Figure 9, but in which the use of coil springs is avoided. Each of the pivot pins 7 is attached to one end of a crank member 15A. The other ends of the crank members 15A, which are associated with adjacent pairs of vanes 1 are linked together by a pin 16, which is free to move in a slot 17 in the wall of the nozzle 2 and in slots in the crank members 15A. Plates 18 are pivotally mounted at 18A about their upstream ends on the outer surface of the wall of the nozzle 2, each adjacent a slot 17. The plates 18 are each connected at their upstream ends to an operating rod 19. The pins 16 in their most upstream position abut the upstream end of the slot 17 in the nozzle wall. In this position of the pins 16 the vanes 1 are in a position shown in full line at 1A. Under the influence of the jet stream the vanes commence to oscillate and the pins 16 are displaced by the crank members 15 to abut the downstream ends of the slots 17. Thus the vanes 1 assume the position 1B shown in broken line. Means are provided for the locking of the vanes in alignment with the jet axis.

Figure 11 shows an arrangement in which the vanes 1 are pivotally mounted on pins 7 and, at a point downstream of the pivot pins 7, the vanes 1 are pivotally interconnected by a linkage 21 which causes all the vanes 1 to oscillate in phase, e.g. all vanes 1 are in position 1A or all vanes in position 1B as shown in respectively in full and broken lines.

WHAT I CLAIM IS:—

1. Apparatus for partially inhibiting the generation of noise by a high velocity fluid jet issuing from a jet pipe nozzle exit into ambient atmosphere, the jet pipe nozzle having mounted substantially radially thereon in the region only of the exit a plurality of vanes, which in an operative position are inclined over a major portion of their length and in non-stalled relationship to the general fluid flow direction through the nozzle.

2. Apparatus as claimed in Claim 1, in which the vanes are mounted on the inner periphery of the nozzle.

3. Apparatus for partially inhibiting the generation of noise by a high velocity fluid jet issuing from a jet pipe nozzle exit into ambient atmosphere, the nozzle having mounted thereon several vanes, which are positioned both on the outer and inner periphery of the nozzle, the inner and outer vanes when in an operative position being inclined with respect to another, and in non-stalled relationship to the fluid flow.

4. Apparatus as claimed in Claims 1 and 3, in which the outer vanes are provided with shrouds.

5. Apparatus as claimed in Claim 4, in which the shrouds are provided with apertures.

6. Apparatus as claimed in any one of Claims 1 to 5, further incorporating means for adjusting the inclination of the vanes with respect to the general direction of flow through the nozzle.

7. Apparatus as claimed in any of Claims 1 to 6, in which the vanes are of twisted form.

nozzle as well as with vanes on the inner periphery of the nozzle, the inner and outer vanes being positioned substantially opposite one another;

Figure 3 shows a nozzzle provided with skewed vanes on the outer periphery of the nozzle as well as with vanes on the inner periphery of the nozzle, the inner and outer vanes being displaced relative to one another;

Figure 4 shows a developed view of the nozzle shown in Figure 3;

Figure 5 shows another view of the nozzle shown in Figure 3;

Figure 6 shows a nozzle similar to that shown in Figure 3, but with the outer vanes shrouded;

Figure 7 shows a nozzle with vanes which are flexibily mounted; and

Figure 8 shows inner and outer vanes which are differentially twisted.

Figure 1 shows a nozzle 2, the inner periphery of which is provided with vanes 1, which project into the jet flow. These vanes are skewed with respect to a plane 3 through the longitudinal axis of both the nozzle and the nozzle wall and deflect the jet flow away from what would have otherwise been the general direction of flow. The vanes tend to produce a flow tangential to the flow in the central region of the jet, the tangential flow entraining ambient fluid and so effecting more rapid mixing between the jet and the ambient fluid, as well as inhibiting the formation of regular annular vortices otherwise formed in the mixing region. The vanes also assist in reducing the axial extent of the mixing region.

Figure 2 shows a nozzle 2 provided with the inner vanes 1, the nozzle being provided around its outer periphery with vanes 4. The inner and outer vanes 1 and 4 are substantially opposite one another and skewed with respect to the plane 3 in a different sense. The ambient fluid flowing through the outer vanes 4 is deflected from what would otherwise have been its direction of flow in an anticlockwise direction (as viewed from the upstream end of the nozzle). The jet flow flowing over the inner vanes 1 is deflected in a clockwise direction. The contra-rotating flows thus formed tend to interact to inhibit the formation of the regular annular vortices in the mixing region and to prevent them growing too large and also to increase the rate of mixing between the ambient and jet flows.

Figure 3 shows a nozzle similar to that shown in Figure 2, except that the vanes 4 are displaced relative to one another.

Figures 4 and 5 show more clearly how the vanes 1 and 4 of the nozzle shown in Figure 3 are differentially skewed.

In Figure 6, the outer vanes 4 are provided with a shroud 5, the shroud having a series of apertures 6 to allow for the entrainment of ambient fluid into the space defined by the vanes 4 and the shroud 5 or the passing of ambient fluid out of this space through these apertures, depending on the pressure conditions obtaining in the space. It is believed that such an arragement will further assist mixing between the jet flow and the ambient fluid.

Any one of the embodiments shown in Figures 1—6 may include means by which the vanes can be brought into planes passing through the longitudinal axis of both the nozzle and the nozzle wall. For this purpose, the vanes may be pivotable about an axis such as the axis 7 shown in Figure 5. When the vanes are brought to lie in the planes referred to, the vanes have little or no noise suppression effect. In an aircraft application, during take-off of an aircraft, the vanes will be skewed at some angle with respect to the plane 3 through the longitudinal axis of the nozzle, but when sufficient altitude has been attained, these vanes can be returned to the inoperative position and thus avoid losses of thrust.

Figure 7 shows a nozzle 2 with vanes 1 mounted downstream of the nozzle exit by flexible means shown for example as coil springs 8. Thus, the vanes 1 can oscillate between inclination angles on either side of the position of equilibrium of the vane at a frequency dependent on the flexibility of the mountings, the velocity of the jet and the ambient flows, the turbulence in the jet flow and the vane inertia. Instead of the coil springs 8, flat spring flexures may be used or the vanes provided with pivots. Inner and outer vanes may be flexibly mounted whether placed downstream or upstream of the nozzle exit.

The oscillation of the vanes induces corresponding oscillation of flow direction of the jet gases and ambient field and consequently inhibits formation of the regular annular vortices as well as reducing the mixing zone length.

Figure 8 shows that the outer vanes 4 may be bent over at their downstream tip and the inner vanes 1 bent over at their downstream tip in a different sense. It is thought that the vanes 1 and 4 being differentially twisted in this way will further assist rapid mixing of the jet and the ambient fluid and restriction of the eddies formed in the turbulent zone.

C. E. BELL,
Chartered Patent Agent,
25, Green Street, London, W.1,
Agent for the Applicant.

ımington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1961.
blished at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

885,093 PROVISIONAL SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale.* SHEETS 1 & 2

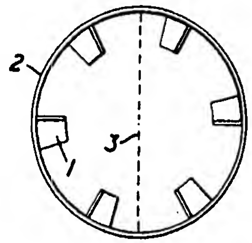

FIG. 1.

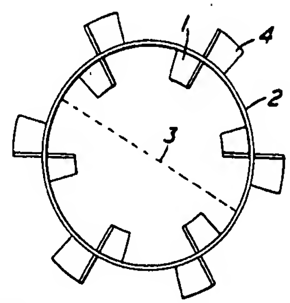

FIG. 2.

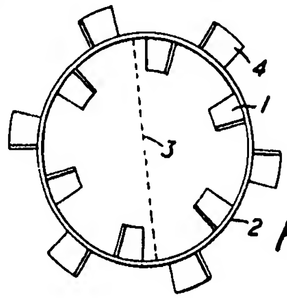

FIG. 3.

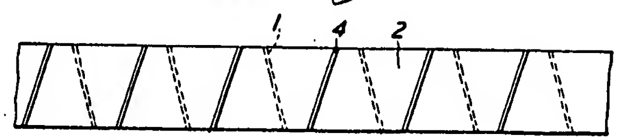

FIG. 4.

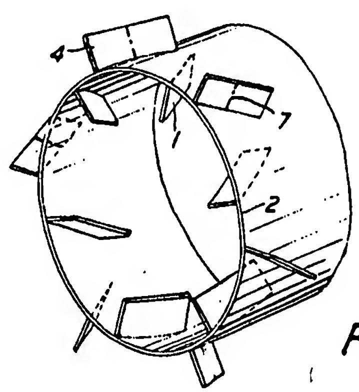

FIG. 5.

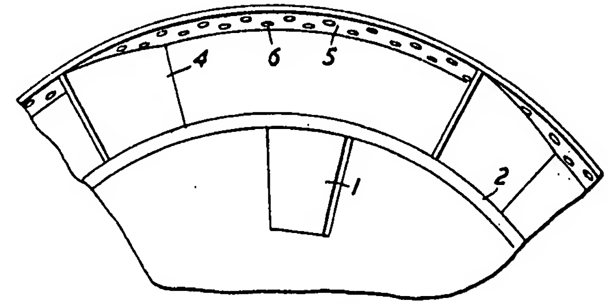

FIG. 6.

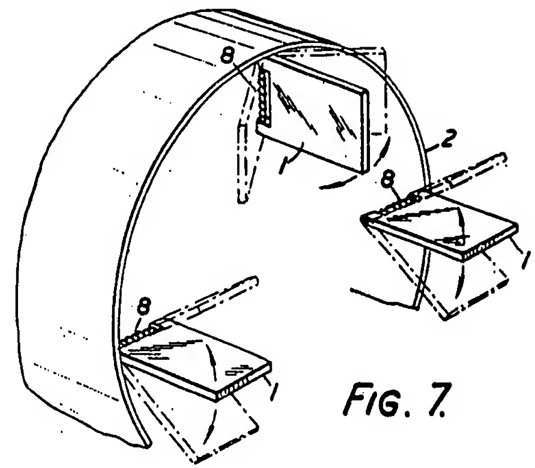

FIG. 7.

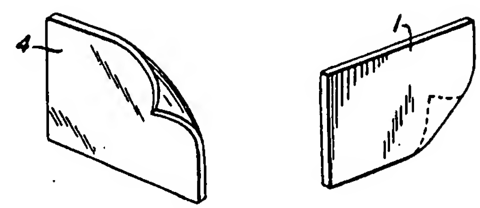

FIG. 8.

885,093 3 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.

SHEET 1

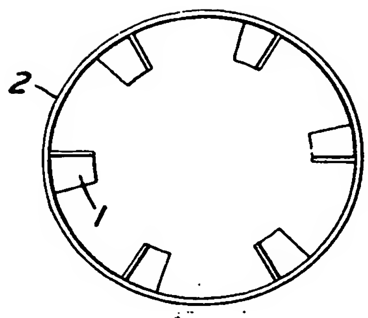

FIG. 1.

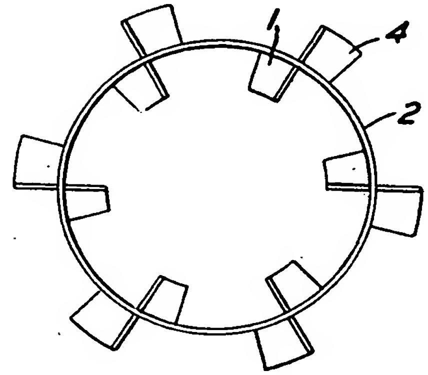

FIG. 2.

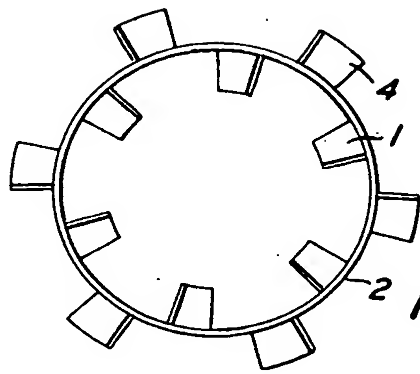

FIG. 3.

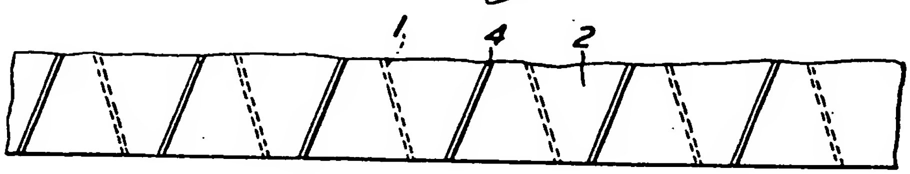

FIG. 4.

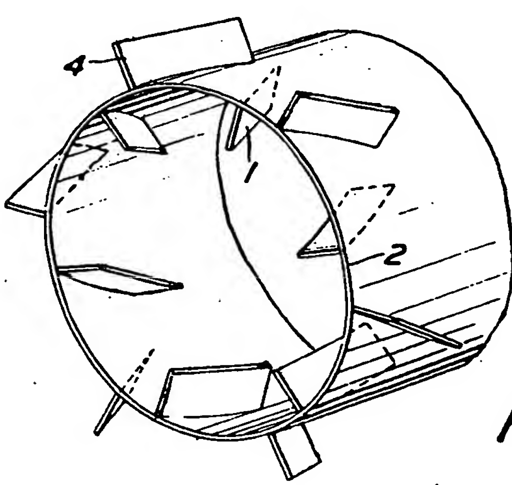

FIG. 5.

885,093 3 SHEETS COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 2 & 3

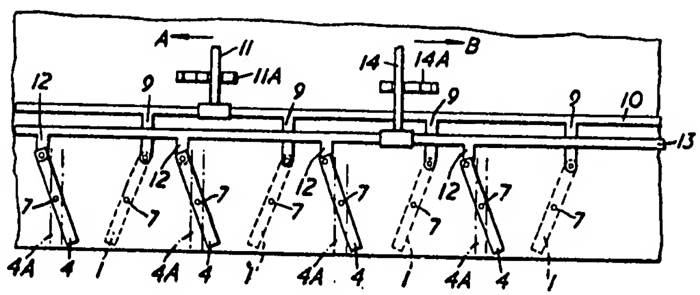

FIG. 6.

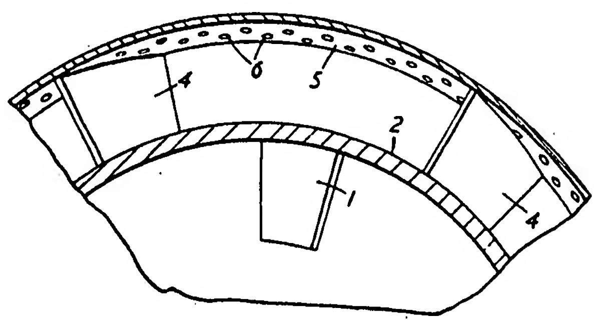

FIG. 7.

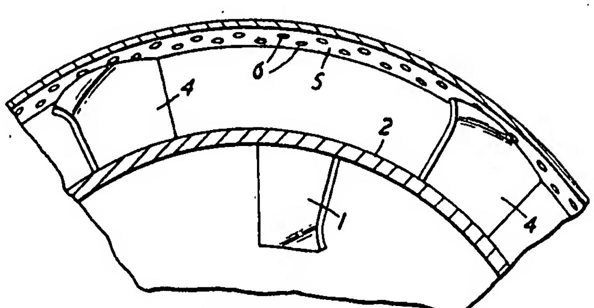

FIG. 8.

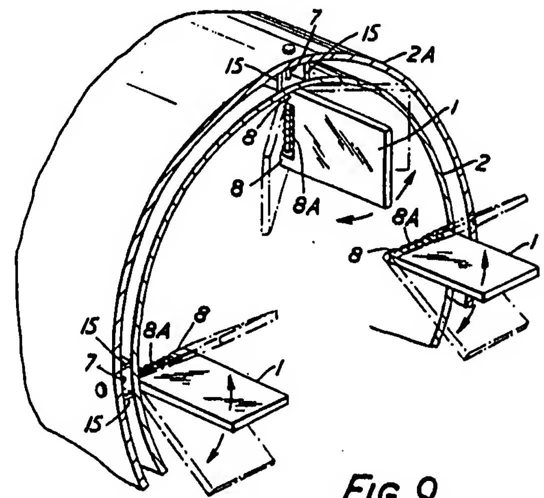

FIG. 9.

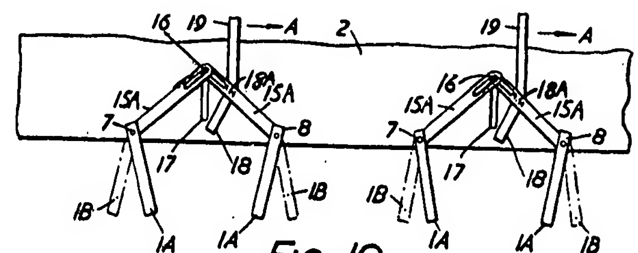

FIG. 10.

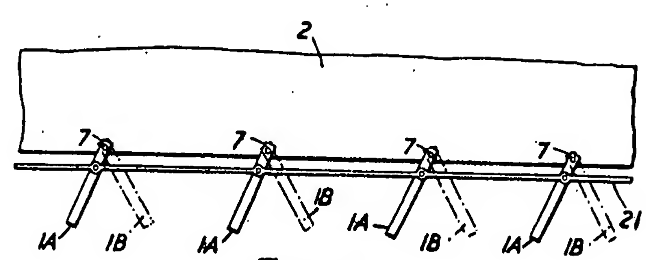

FIG. 11.